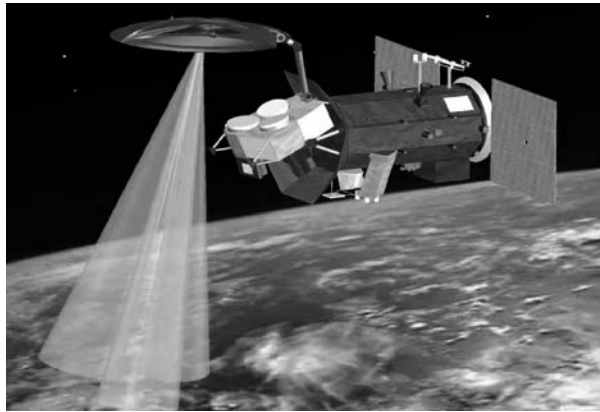


# Aquarius



**Aquarius URL**  
aquarius.gsfc.nasa.gov

## Summary

Aquarius is a joint U.S. (NASA)/Argentine (Comisión Nacional de Actividades Espaciales [CONAE]) venture. The mission will enhance the understanding of the climatic interactions between the global water cycle and ocean circulation by systematically mapping the spatial and temporal variations of sea surface salinity (SSS). It will measure SSS variability, the key tracer for freshwater input and output to the ocean associated with precipitation, evaporation, ice melting, and river runoff. These measurements, along with sea surface temperature (SST) from other satellites, will allow determination of the sea surface density, which controls the formation of water masses and regulates the 3-dimensional ocean circulation.

## Instrument

- Aquarius Instrument

*Note:* Aquarius is part of the Aquarius/Satellite de Aplicaciones Científicas (SAC)-D mission in partnership with the Argentine space agency CONAE. The CONAE SAC-D payload includes other scientific instruments not described in detail in this document. The SAC-D mission is described in detail at: [www.conae.gov.ar/eng/satelites/sac-d.html](http://www.conae.gov.ar/eng/satelites/sac-d.html).

## Points of Contact

- *Aquarius Principal Investigator:* Gary Lagerloef, Earth & Space Research (ESR)
- *Aquarius Deputy Principal Investigator:* David Le Vine, NASA Goddard Space Flight Center

## Key Aquarius Facts

Joint with Argentina

### Orbit:

Type: Sun-synchronous  
Equatorial Crossing (ascending node): 6 a.m.  
Altitude: 657 km  
Inclination: 98.01°  
Period: 97.74 minutes  
Repeat Cycle: 7 days (103 orbits)

*Dimensions:* 4.9 m (ht) × 2.7 m (diameter), stowed;  
6.2 m (ht) × 2.7 m (diameter), deployed

*Mass:* 1515 kg

*Power:* 1300 W End of Life

*Downlink:* S-band @ 4 kbps for real time housekeeping; X-band @ >13.5 mbps for stored and real time science data.

*Design Life:* 3 years

*Contributors:* CONAE, NASA JPL, NASA GSFC

## Other Key Personnel

- *Aquarius Project Scientist:* Yi Chao, NASA Jet Propulsion Laboratory/California Institute of Technology
- *Aquarius Project Manager:* Amit Sen, NASA Jet Propulsion Laboratory/California Institute of Technology
- *Aquarius Deputy Project Manager:* Yunjin Kim, NASA Jet Propulsion Laboratory/California Institute of Technology
- *Aquarius Program Scientist:* Eric Lindstrom, NASA Headquarters
- *Aquarius Program Executive:* Eric Ianson, NASA Headquarters
- *SAC-D Principal Investigator:* F. Raul Colomb, CONAE
- *SAC-D Project Manager:* C. Daniel Caruso, CONAE

## Mission Type

Next Generation Exploratory Mission (Earth System Science Pathfinder)

## Launch

- *Date and Location:* No earlier than 2009, from Vandenberg Air Force Base, California
- *Vehicle:* Delta II 7320-10C

## Relevant Science Focus Areas

(see NASA's Earth Science Program section)

- Climate Variability and Change
- Water and Energy Cycles

## Related Applications

(see Applied Sciences Program section)

- Agricultural Efficiency
- Water Management

*Note:* Applications listed regard coarse soil moisture measurements that can be derived using Aquarius.

## Aquarius Science Goals

- Observe and model the processes that relate salinity variations to climatic changes in the global cycling of water.
- Understand how these variations influence the general ocean circulation.

## Aquarius Mission Background

### Sea Surface Salinity (SSS) Studies

The global mean surface-salinity pattern, as we know it today, reveals fundamental connections to the global water cycle. Lower salinity is generally found in the precipitation-dominated tropics and sub-polar regions, whereas higher salinity is found in the dry subtropics where evaporation dominates. SSS imbalances are seen between basins, with the Atlantic being the saltiest of the major oceans. Alternative theories exist for how this structure is maintained and involve partly a net loss of surface water through excess evaporation from the Atlantic that is carried by the atmosphere and deposited in other basins through rainfall. The enhanced salinity allows denser waters to form in the high-latitude North Atlantic and drive the ocean's overturning 'conveyor' circulation that regulates Earth's climate. Abrupt climate shifts in the recent geological past, sometimes occurring in less than a decade, have been traced to changes in the overturning circulation that are attributed to SSS changes in the sub-polar North Atlantic.

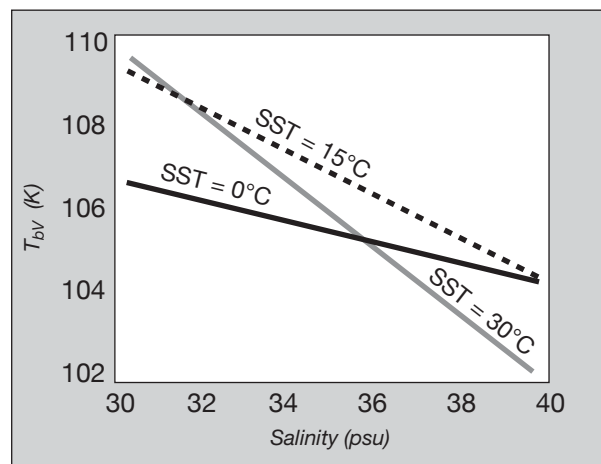
Although the present oceanographic knowledge of the global SSS distribution provides useful climate-modeling information, there is little more that can be done with the existing mean SSS field and estimated annual cycle. The contemporary oceanographic knowledge of salinity

at the surface and deep-ocean has been derived from the compendium of ship and some buoy observations acquired over the past 125 years. Nevertheless, the SSS sampling has been sparse, irregular, and largely confined to shipping lanes and the summer season. About 25% of the 1° latitude-longitude squares in the ice-free oceans have never been sampled, including vast regions of the Southern Hemisphere, and greater than 73% have fewer than 10 observations. Global satellite observations are essential to advance the present modeling and physical understanding because they are the only means to portray the evolving global synoptic SSS in conjunction with simultaneously available observations of precipitation, evaporation, wind, surface currents, sea ice changes, and SST.

## Aquarius Goals and Objectives

The Aquarius mission responds to this need for global observation of SSS. Its science goals are to observe and model the processes that relate salinity variations to climatic changes in the global cycling of water and to understand how these variations influence the general ocean circulation. By measuring salinity globally and synoptically for three years, Aquarius is expected to provide an unprecedented view of the ocean's role in climate and new insights into ocean circulation and mixing processes. Specifically, science objectives and expectations include:

*Discovery and Exploration:* Aquarius will resolve unknown patterns and variations of the global SSS field, especially in large under-sampled regions. Aquarius will provide an important reference from which longer-term climatic ocean changes will be detected in the future.



$T_b$  varies linearly with SSS, with a different slope and offset as SST increases. Sensitivity to changes in SSS over the range of open ocean conditions is greatest in warm water (0.7 K/psu) and least in cold (0.3 K/psu). The curves in this figure are for the vertical polarized  $T_{bv}$  signal, with an incidence angle of 34°.

*Water Cycle:* Aquarius will measure spatial and temporal salinity variations to determine how the ocean responds to varying evaporation-minus-precipitation (E-P) surface-water fluxes, ice melt and river runoff on seasonal and interannual time scales.

*Ocean Circulation and Climate:* Aquarius will investigate how salinity variations modify ocean density and influence density-driven circulation and heat flux in three latitude zones:

- *Tropics:* Air-sea interactions and climate-feedback processes, El Niño/La Niña variations.
- *Mid-Latitudes:* Formation processes of surface-mode waters and their subduction into the ocean interior. (Surface-mode waters carry unique surface temperature and salinity signatures to intermediate depths and serve as tracers for ocean interior circulation.)
- *High Latitudes:* Salinity anomalies that influence the ocean's large-scale overturning circulation and have lasting impacts on climate.

Ancillary science objectives include analyzing air-sea CO<sub>2</sub> flux, monitoring sea ice concentration, and retrieving soil moisture while the satellite is over land.

## Measurement Objectives and Approach

Aquarius' science objectives are oriented toward large-scale measurements and long time scales such that the mean, seasonal cycle, and interannual variations are resolved. These will be met by providing monthly average global maps with 150-km spacing and the best possible measurement accuracy. Aquarius is designed to provide composite global maps every seven days specifically to achieve further error reduction by objective interpolation into monthly composites. The 7-day global coverage dictated a minimum swath width of about 350 km, and the spatial requirement dictated a maximum footprint size of about 150 km. These two requirements led to the three-beam configuration. The 3-year mission life is required to obtain a robust map of the climatological mean and seasonal cycle as well as to observe interannual variations. Monthly error requirements are < 0.2 practical salinity units (psu). Spatial or temporal averaging can reduce the residual retrieval error further.

The basis for remote sensing of SSS is the dependence of the dielectric constant of sea water on salinity at microwave frequencies. The dielectric constant determines the surface emissivity ( $\epsilon$ ), and this determines the measurable parameter, the brightness temperature  $T_b$ , by the relationship  $T_b = \epsilon(\text{SST})$ , where SST is the physical temperature of the seawater. At L-band (1.4 GHz) for values of SSS (32–37 psu) and SST typical of the open ocean, the dynamic range of  $T_b$  is ~4 K. The 1.413 GHz frequency was chosen because of its sensitivity to salinity and it is in a protected radio-frequency (RF) band. The SSS sensitivity is almost negligible above 3 GHz. At lower frequencies, the larger antenna size, and ionospheric and RF interference, make the measurement imprac-

## Key Aquarius Instrument Facts

### Heritage:

L-Band Radiometer: TRMM/TMI, PALS, AMSR, AMSR-E, ESTAR, SLFMR

L-Band Scatterometer: SeaWinds (on QuikSCAT and ADEOS-II), PALS

*Instrument Type:* L-Band Radiometer and Scatterometer

*Scan:* 3-beam push broom with > 350-km swath width (current design)

*Accuracy:* 0.2 psu rms, monthly, at 150-km resolution

*Calibration:* Global ocean-observing system surface *in situ* salinity observations (>10,000/month)

*Duty Cycle:* Continuous

*Data Rate:* 14.6 kbps; 158 MB/day

*FOV:*  $\pm 10.3^\circ$  (~350 km swath), center displaced  $33^\circ$  off nadir to shadow side of 6 p.m. orbit

*Incidence Angle:*  $29^\circ$ ,  $38^\circ$ ,  $46^\circ$  (3 different fixed antenna beams)

*Instrument IFOV:* 3 beams  $5.9^\circ$ – $7.0^\circ$  (footprint: 76 km  $\times$  94 km, 84 km  $\times$  121 km, 97 km  $\times$  157 km)

### Dimensions:

Instrument: 3.7 m (ht)  $\times$  3.7 (diameter), antenna deployed

Antenna aperture: 2.5-m parabolic reflector, offset feeds

*Mass:* 400 kg (Aquarius Instrument)

*Power:* 450 W (Aquarius Instrument)

*Platform Pointing Requirements (Platform + Instrument,  $3\sigma$ ):*

Control:  $0.5^\circ$

Knowledge:  $0.1^\circ$

Stability:  $0.1^\circ/\text{s}$  (< 1 Hz, > 0.1 Hz)

*Temperature Resolution:* Radiometer Brightness Temperature ( $T_b$ ): 0.15 K (calibration), 0.06 K noise equivalent delta temperature ( $\text{NE}\Delta T$ )

*Temporal Resolution:* Minimum 8 samples per month per 150-km square at equator

*Thermal Control:* Active

*Transmission Frequency:* Scatterometer at 1.26 GHz, polarimetric

*Measured Frequency:* Radiometer 1.413 GHz

*Repeat Cycle:* 7 days, 103 orbits

tical. At L-band frequencies, the penetration depth of the ocean surface is about 1 cm.

### Validation Program

The Aquarius Validation Plan is designed to minimize the measurement error of the retrieved salinity data, improve algorithms and monitor the long-term stability of the sensors during the operational phase. The plan will center on an extensive *in situ* surface measurement program. This will be supplemented with additional calibration strategies primarily for monitoring long-term stability of the radiometer and scatterometer, including vicarious calibration techniques, possible stable ground targets, and occasional cold-sky viewing as needed.

Aquarius *in situ* surface-salinity validation data will be obtained from moored and drifting buoys, Volunteer Observing Ships (VOS), and the automated Argo profiling-buoy array. There will be up to 3000 observations per Aquarius 7-day repeat cycle. All systems will be fully automated with routine data telemetry via satellite and data delivery within one day. These measurements will be applied to validate Aquarius SSS retrievals and generate the scientific data set comprising the blended analysis of satellite and *in situ* salinity data.

## Aquarius Instrument

This instrument consists of a radiometer operating in the protected passive-frequency band at 1.413 GHz and a scatterometer in the space-radar band at 1.26 GHz. The radiometer is the primary sensor for SSS, and the scatterometer provides a critical correction for surface roughness. Both instruments will be fully polarimetric to provide information to correct for the Faraday rotation from the ionosphere. Aquarius will use a 2.5-m-diameter offset-feed parabolic reflector, with three feed horns providing three beams in a push-broom configuration. These beams are pointed at 24°, 36°, and 40° incidence angles towards the shaded side of the orbit to reduce the effects of solar reflection and radiation. The resultant swath will give complete global coverage in 7 days and enough samples within a month to achieve the accuracy < 0.2 psu through averaging.

The sun-synchronous orbit was selected to provide a stable thermal environment enabling excellent mechanical and electrical stability. Analyses of the reflector, feed, and support structure designs have shown that this assembly will have the structural stability to meet the on-orbit antenna-pointing knowledge of 0.1° (3σ) even during the eclipse periods during the summer solstice. The instrument thermal design will use an active thermal-control system to achieve temperature stability within 0.1° C RMS for the critical front-end components.

### Aquarius Instrument URL

[aquarius.gsfc.nasa.gov](http://aquarius.gsfc.nasa.gov)

### Key Aquarius Instrument Facts

(cont.)

*Sampling Interval:* 10 ms (radiometer);  
< 2 ms (scatterometer)

*Spatial Resolution:* 76 km × 94 km,  
84 km × 121 km, 97 km × 157 km

*Spectral Range:* 1.413 GHz ± 13 MHz  
bandwidth (passive), 1.26 GHz ± 2 MHz  
polarimetric (active)

*Standard Profile Spacing:* Swath gaps  
≤ 50 km

*Swath:* > 350 km

*System Temperature:* -30° C – +30° C

## Aquarius Data Products

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
<b>Aquarius Instrument</b>			
Raw Radiometer Data	0	Global Ocean poleward to $\pm 77^\circ$ Latitude	85–133-km horizontal resolution/7-day
Raw Radar Data	0	Global Ocean $\pm 77^\circ$ Latitude	64–103-km horizontal resolution/7-day
Radiometer Brightness Temperature	1B	Global Ocean $\pm 77^\circ$ Latitude	85–133-km horizontal resolution/7-day
Radar Backscatter	1B	Global Ocean $\pm 77^\circ$ Latitude	64–103-km horizontal resolution/7-day
Calibrated/Geolocated SSS	2B	Global Ocean $\pm 77^\circ$ Latitude	85–133-km horizontal resolution/7-day
Gridded SSS from Aquarius data alone	3B	Global Ocean $\pm 77^\circ$ Latitude	150-km horizontal resolution/monthly
Gridded SSS merging Aquarius and <i>in situ</i> data	3B	Global Ocean $\pm 77^\circ$ Latitude	150-km horizontal resolution/monthly

### Aquarius Data Products